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CONTROL OF PERICARP BROWNING AND QUALITY RETENTION OF LITCHI FRUIT BY POST-HARVEST TREATMENTS AND MODIFIED ATMOSPHERE PACKAGING

RAMANDEEP KAUR[1], ASHOK KUMAR[2], BVC MAHAJAN[3] & M JAVED[4]

[1,2]Department of Processing and Food Engineering, Punjab Agricultural University, Ludhiana, Punjab, India

[3]Punjab Horticulture Post-harvest Technology Centre, Punjab Agricultural University, Ludhiana, Punjab, India

[4]Department of Maths, Statistics and Physics, Punjab Agricultural University, Ludhiana, Punjab, India

ABSTRACT

Litchi (*Litchi chinensis* Sonn.) is one of the most desirable subtropical fruits. Pericarp browning is the major constraint affecting the commercial quality of litchi. The present study was undertaken with the objective to analyse the effects of salicylic acid in combination and comparison to sulphur dioxide (SO_2) fumigation coupled with modified atmosphere packaging on quality retention of litchi. Therefore, the litchi fruits cv. 'Culcuttia' were treated with SO_2, salicylic acid (SA) (0.25 and 0.5%) in combination with modified atmosphere packaging (MAP). The treated fruits were packed in perforated low density polyethylene (LDPE) packages (100 gauge) and stored in walk-in cool chambers at 2±1°C and 90-95% RH. The fruits were evaluated for various physiological and biochemical parameters at weekly interval for a duration of 35 days. The combined effect of SO_2+0.5%SA+perforated LDPE resulted in lowering the weight and firmness loss, reduced decay incidence and browning index and maintained TSS, titratable acidity, ascorbic acid, colour and anthocyanin content of fruits during storage. This treatment also minimised the respiratory activities, by lowering the concentration of oxygen (6.3%) and increasing the concentration of carbon dioxide (7.5%), thus modifying the atmosphere inside the package and maintaining the shelf-life of litchi fruits upto 21 days with acceptable quality. The fruits treated with sulphur dioxide alone showed negative effect on colour, taste and developed off flavours after 14 days of storage. The untreated control fruits maintained the overall quality for 7 days only.

KEYWORDS: Litchi, Browning, Decay, Sulphur Fumigation, Salicylic acid, Acid, Modified Atmosphere Packaging

INTRODUCTION

Litchi (*Litchi chinensis*) is a delicious juicy fruit of excellent quality. Botanically it belongs to Sapindaceae family. The translucent, flavoured aril or edible flesh of the litchi is popular as a table fruit in India, while in China and Japan it is preferred in dried or canned state. India is the second largest producer of litchi in the World after China. Other major producing countries are Thailand, Australia, South Africa, Madagascar and Florida in US. Due to very short production season of around two months in a year, market gluts leading to distress sale. The short span of fruit availability coupled with poor shelf life limits the duration of availability of litchi fruits in the domestic as well as international market. Shelf life of litchi fruits varies from 2 to 3 days under ambient conditions. As a nonclimacteric, litchi fruit does not ripe or develop full flavour once harvested (Kays 1991; Zauberman et al. 1991). Furthermore, after harvest, fruits quickly deteriorate due to rapid water loss, associated with pericarp surface browning (Scott et al. 1982; Underhill & Critchley, 1994). Pericarp browning is a major post-harvest problem, which renders the fruit unmarketable. Browning is associated with desiccation. Peroxidase activity coupled with ascorbic acid oxidation enhances anthocyanin degradation resulting in

enzymatic browning of litchi. With proper post-harvest treatments, the shelf life can be extended upto 2-3 weeks. Several approaches like sulphur fumigation, pre-cooling, heat treatment, wax coating, vinyl resin plastic coating, acidification, irradiation, packing in plastic films, fumigation with ethylene bromide and low temperature storage have been tried to retard the browning and prolong the shelf-life of litchi. Recently, antioxidants like N-acetyl cysteine, isoascorbic acid have been found very effective in reducing the browning and preventing the postharvest decay of fruits and vegetables. Of these treatments, fumigation with sulphur dioxide has been primarily used to prevent litchi pericarp browning (Ducamp-Collin et al. 2008 and Silva D F P et al. 2012).

Sulphur fumigation bleaches the colour of the pericarp. However, the bleached fruits gradually regain the pink colour but do not restore the red colour properly. Therefore, a consecutive treatment preferably with acid is necessary to help restore the red colour. Salicylic acid (SA) (C7H6O3), the active ingredient of aspirin, has been reported to regulate a number of processes in plants. Salicylic acid belongs to a group of phenolic compounds, widely distributed in plants and is now considered as a hormonal substance, playing an important role in regulating a large number of physiological processes.

It has been proposed that salicylic acid has an antagonistic effect on ethylene biosynthesis and/or ethylene action (Raskin 1992). It has been found to delay the senescence of fruits (Hassan et al. 2007). Application of exogenous salicylic acid at non-toxic concentration to fruits has been shown to delay the ripening and softening of bananas (Srivastava and Diwedi 2000) and kiwifruits (Zhang et al. 2003), reduce lipid peroxidation of navel orange (Huang et al. 2008). The work done on this chemical is scanty.

The objective of the present research aimed to evaluate the application of salicylic acid in combination and comparison to SO_2 fumigation in association with MAP on browning, decay and retention of overall fruit quality during storage of litchi under low temperature and high RH conditions.

MATERIALS AND METHODS

Preparation of Sample

Fruits of litchi cultivar 'Calcutta' were procured from Punjab Agricultural University research station Gangian. The fruits were harvested at commercial maturity, having a bright red colour. The stalks of the fruits were removed and the left fruits were sorted and graded to obtain fruits of uniform size, shape, colour and free from any sort of damage or decay.

Post-Harvest Treatments

The fruits were subjected to sulphur fumigation (SO_2) (0.6g sulphur/kg of fruit) for 20 min, a dip treatment with salicylic acid (0.25 and 5%) alone, for 2 minutes and a combined treatment of SO_2 fumigation and salicylic acid. After the treatments, the fruits were air dried.

Modified Atmosphere Packaging

The treated fruits were packed in LDPE packages of 100 gauge with 14 perforations of 1mm to meet the respiration rate of the fruit. The packages were sealed using an electronic sealer. The packages were kept at 2±1°C and 90-95% RH in walk-in cool chambers. Fruits without packaging and without treatment were taken as control.

Head-Space Gas Analysis

Head-space gases oxygen (O_2) and carbon dioxide (CO_2) were measured using PBI Dansensor CO_2/O_2 gas analyzer (Ringsted, Denmark), after removal from the walk-in cool chambers. Three replicates of each kind of MAP containing fruit with or without post-harvest treatments were analysed for gas concentration.

Physiological Loss in Weight

Weight of all the samples kept in LDPE packages as well as control samples was recorded daily using an electronic weighing balance having least count 0.001g. The physiological loss in weight (%) of the samples was computed daily on the basis of the initial weight of the produce, using the following formula:

$$PLW\ (\%) = 100 \times \frac{W_1}{W_2}$$

Where W_1 and W_2 are the initial and final weights of the fruits in grams (Mangaraj and Goswami, 2011).

Browning Assessment and Decay Incidence

Severity of browning was assessed visually, by measuring the extent of the total brown area on each fruit pericarp using 10 fruits, with the following scale: 1= no browning; 2=1-2 brown spots, acceptable marketability; 3= some spots with browning, limited marketability; 4= 50% browning; 5=75% browning and entire fruit surface brown (Zhang and Quantick, 1997; Sivakumar and Korsten,2010). The browning index was calculated as:

$$BI = \sum(browning\ scale \times percentage\ of\ fruit\ within\ each\ class)$$

Fruits having browning index >3 were rendered unacceptable for market.

Decayed fruits due to post-harvest disease were assessed by observing visible fungal or bacterial growth on the fruit surface. Decay incidence (DI) was evaluated on a 1-5 scale, describing the severity of post-harvest decay as: 1=none; 2=slight (upto 5% surface affected); 3=moderate (5-20% surface affected); 4=moderately severe (20-50% surface affected); 5=extreme (>50% surface affected) (Liu et al. 2011). Decay incidence was calculated as:

$$DI = \sum \frac{(decay\ score \times fruit\ within\ each\ class)}{total\ fruit \times highest\ score}$$

Anthocyanin Content

100 g of the fruit peel was blended with 100 ml of ethanolic hydrochloric acid in a blender, transferred to a 500 ml bottle and stored overnight at 4°C. The blend was filtered through a What man No. 1 paper using Buchner funnel and 450 ml of the extract was collected. Diluted small aliquot (2ml) of the filtrate was taken for the absorbance at 535 nm at a spectrophotometer. Total anthocyanin was calculated using the formula given by Ranganna 1995.

$$Total\ Anthocyanin\ content = \frac{total\ OD\ per\ 100\ g\ of\ fruit}{E\ value}$$

Total anthocyanin content was expressed as mg%.

Colour Measurement

The Colour Reader CR-10 (Konica Minolta Sensing Inc. USA) was used for the measurement of colour of the

fruit. Colour parameters (l, a and b) of the skin surfaces of the fruit were recorded at D 65/10°, under proper lighting at regular intervals.

Texture Analysis

Fruit firmness was measured using Texture Analyser (Model TA-XSO2+PERFORATED LDPEi, Stable Microsystems Ltd. UK). A cylindrical probe of 5 mm, with a load cell of 25 kg and test speed of 0.5 mm/s. Corresponding maximum force in Newton (N) was recorded as the firmness of test sample.

Total Soluble Solids (TSS), Titratable Acidity and Ascorbic Acid Concentration

TSS, titratable acidity and ascorbic acid concentration of fruits were analysed during storage. The juice was extracted from the fruit and filtered using a muslin cloth. TSS (°Brix) of the juice was determined using a hand refractometer (Erma, Japan). Titratable acidity was determined by titrating 2 ml of the juice with 0.1 N NaOH, using a few drops of 1% phenolphthalein as indicator. Titratable acidity was expressed as % malic acid. The ascorbic acid was determined by visual titration using 2,6-dichlorophenol-indophenol. Ascorbic acid was expressed as mg/100 ml of juice (Ranganna 1995).

Overall Acceptability

A panel of 10 members assessed overall quality of litchi fruits taking into account the following attributes: colour of skin, taste, flavour and firmness on a 9-point hedonic scale (9-like extremely, 5-neither like nor dislike and 1-dislike extremely). The samples with score below 7 were rejected (Sivakumar and Korsten, 2010).

Statistical Analysis

All the experiments were performed with three replications and the data were subjected to analysis of variance (ANOVA) using SPSS version 16.0.2, in order to study the effects of treatments. Tukey's test was applied to see the mean difference between treatments and to determine which treatments were significantly different at 5% level.

RESULTS AND DISCUSSIONS

Head-Space Gas Analysis

There was a significant depletion ($p \leq 0.05$) in oxygen level for all the samples in the packages and a consequent increase in carbon dioxide evolution, during storage (Figure 1 (a) and (b)). Analysis of gas composition within the packages revealed elevated CO_2 (14.7%) and low O_2 (3.2%) concentrations in SO_2+perforated LDPE fruits. However SO_2+0.25% SA+ perforated LDPE and SO_2+0.5% SA+ perforated LDPE fruits enabled a passive modified atmosphere to form inside the packages (~ 7.5 % CO_2 and 6.3% O_2) at 2±1°C and 90-95% RH, close to the controlled atmosphere conditions recommended for storage of litchi, thus extending the shelf-life of litchi. Though, the treatments combined with MAP showed similar patterns of variations with respect to in package CO_2 and O_2 composition, the post-harvest dip treatments affected the gas composition within different MA packages.

Physiological Loss in Weight

Physiological loss in weight was significantly higher ($p \leq 0.05$) in untreated control fruits than in the fruits subjected to SA, SO_2 fumigation alone and in combination with SA and packed in perforated LDPE packages. On 35th day of storage, the physiological loss in weight of control fruits was 2.00%, for SO_2+perforated LDPE fruits was 1.10% and for

0.25% SA+ perforated LDPE and 0.5% SA+ perforated LDPE, it was 1.02 and 1.01% respectively. Whereas, the values were less for fruits treated with SO_2+0.25% SA+ perforated LDPE and SO_2+0.5% SA+ perforated LDPE, 0.89% (Table 1). No significant difference was found among the treatments 0.25% SA+ perforated LDPE & 0.5% SA+ perforated LDPE and SO_2+0.25% SA+ perforated LDPE & SO_2+0.5% SA+ perforated LDPE. The reduction in weight loss in MAP is due to prevention of water loss and soluble solid content (Mangaraj and Goswami, 2011). Under high RH and low temperature, respiration is reduced. Also lower O_2 and high CO_2 affects metabolic enzymatic activities and respiration, causing less substrate utilization and reduced weight loss.

Pericarp Browning and Decay Incidence

It is evident from the data that pericarp browning index of litchi fruit rapidly increased during storage. Treating fruits with salicylic acid alleviated pericarp browning to some extent compared to SO_2 fumigated fruits and control fruits (Figure 1 (c)). A significant ($p \leq 0.05$) increase in browning index (BI) was observed for the fruits treated with SA+ perforated LDPE alone and control samples. The browning indices of the fruits treated with 0.25 and 0.5% SA+ perforated LDPE were lower than that of control fruits during storage. A BI of 4.7 was observed in control fruits, and a BI of 2.3 and 2 was observed for 0.25% SA+ perforated LDPE and 0.5%SA+perforated LDPE, respectively after 21 days of storage. On the contrary, BI of 1 was observed for SO_2+perforated LDPE, SO_2+0.25% SA+ perforated LDPE and SO_2+0.5% SA+ perforated LDPE, after 21 days of storage, indicating no browning of the pericarp. Browning is associated with desiccation (Scott et al. 1982) and also associated to degradation of anthocyanin by PPO, POD and enzymatic oxidation of ascorbic acid (Underhill 1992; Holcroft and Mitcham, 1996). It was observed that PPO is activated by moisture loss from the fruit and treatments to reduce desiccation also reduced browning (Taylor 1993). The decrease in BI is attributed to reduced desiccation due to high RH around the package and maintenance of low pH which hinders the activities of enzymes. SO_2 is an effective antioxidant and contributes to oxygen reduction thereby making it unavailable for oxidizing polyphenol constituents or combining with quinines (Neog and Saikia 2010; Liang et al. 2012). This inhibition of PPO activity by SO_2 is also well documented (Zauberman et al. 1991). Dipping the fruits in low pH solution resulted in lower pericarp pH which had inhibitory effect on browning promoting enzymes, retarding the development of enzymatic browning and stabilizing anthocyanins. The fruits treated with SA only had a red colour with dark patches.

Treating litchi fruits with SO_2 and salicylic acid, had a marked effect on inhibition of spoilage pathogens during storage. Decay incidence was not observed upto 21 days in fruits treated with SO_2 and salicylic acid (0.25 and 0.5%). However, about 38.42% of control fruits began to rot after 7 days of storage. Fruits fumigated with SO_2 alone showed 9.98% decay incidence on 21st day of storage, whereas fruits treated with 0.25 and 0.5% salicylic acid showed 6.72 and 5.61% decay after 21 days of storage, respectively (Figure 1 (d)). Treatment with 0.5% salicylic acid significantly supressed decay development. Salicylic acid treatment has shown to be effective in eliciting host defence response in tobacco leaves (Chen et al. 1993). Application of salicylic acid proved effective in inhibiting disease development in mango and strawberry (Zainuri et al. 2001 and Shafiee et al. 2007). The study by Kumar et al. (2013) indicated the beneficial effect of 0.5 and 1% SA in reducing decay incidence in litchi cv. Rose scented. It was reported that keeping fruits and vegetables in low O_2 atmosphere reduced physiological disorders and disease incidence (Pesis et al. 2002; Bonghi et al. 1999; Chen et al. 2011) and also low temperatures (0-1°C) are effective in controlling decay (Roth 1963).

Anthocyanin Content

The control and SA+ perforated LDPE fruits initially had higher concentration of anthocyanin, which decreased significantly ($p \leq 0.05$) with storage time (Figure 1(e)). Results show that minimum percent decrease in anthocyanin content was recorded in 0.5% SA+ perforated LDPE fruits compared 0.25% SA+ perforated LDPE and control fruits. On contrary, the fruits subjected to SO_2 fumigation alone and along with SA dip, initially had low anthocyanin concentration due to bleaching of pericarp, which turns to a uniform pink colour after few days of application, resulting in an increase in anthocyanin content. Among the fruits under observation, fruits treated with acid and SO_2 had a higher anthocyanin content which could be due to stabilization of anthocyanin pigments (Zauberman et al. 1991). The browning and degradation of anthocyanins is directly related with the polyphenol oxidase activity (Lin et al. 1988). A decrease in pH reduces the activity of PPO. In this study, it was observed that salicylic acid reduced the degradation of anthocyanins and hence browning by slowing down the activity of polyphenol oxidase (Kumar et al. 2013), by maintaining low pH.

Colour

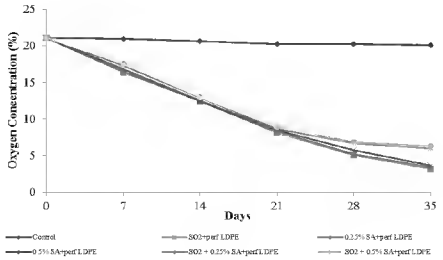
Colour is one of the most important attributes for litchi. Co-ordinate L*, representing lightness of colour, was found to range between 43.97-44.39 for control and only acid treated fruits and was approximately 70 for SO_2 fumigated fruits, on initial day of storage (Table 1). The L* value decreased significantly ($p \leq 0.05$) during storage for all the samples. The initial increase in L* value for SO_2 fumigated fruits was due to bleaching of the pericarp which resulted in high L* value for the fumigated fruits. The overall decrease in the L* value during storage may be attributed to loss of brightness of the pericarp as a result of browning. SO_2+0.25% SA+ perforated LDPE and SO_2+0.5% SA+ perforated LDPE, however retained higher L* values. a* co-ordinate represents red colour of the pericarp. Initially at 0 day, a* value for control fruits and SA treated fruits was approximately 28 and approximately 1.70 for integrated treatment of SO_2 and SA treated fruits. A decrease in a* value was observed for control fruits and fruits treated with SA, whereas an increase in a* value was recorded for SO_2 treated fruits alone and in combination with acid. Due to bleaching of red colour in SO_2 treated fruits, the a* value declined drastically. The SO_2 treated fruits slowly regained the pink colour with storage duration. Retention of colour was more in the fruits treated with SO_2+0.25% SA+ perforated LDPE and SO_2+0.5% SA+ perforated LDPE, though no significant difference was observed among the fruits given SO_2 fumigation. The parameters L* and a* are the critical factors for the successful commercialization of the fruit. Smaller the value of a*, less is the intensity of red colour (Silva et al. 2012). An undesirable change in colour of litchi, shown by rapid reduction in L* value indicates pericarp browning and loss of intense red colour and its consequent loss of commercial value (Solomon et al. 2012).

A decline in b* value was observed for all treatments during storage. Initially b* value was higher for the fruits subjected to SO_2 fumigation (~25) compared to the fruits which were not SO_2 fumigated. This was because fumigation causes the pericarp to become yellow as a result of bleaching of the pericarp. It was inferred from the study that fruits treated with SO_2+ 0.5% SA+ perforated LDPE, retained comparatively higher L*,a*,b* values, indicating a reddish yellow coloured fruit, followed by SO_2+ 0.25%SA+perforated LDPE. Control fruits and fruits treated with acid alone lost their attractive red colour and consequently quality and marketability. The acid treatment following sulphur fumigation stabilizes the anthocyanin pigments (Ketsa et al 1992 and Liang et al 2012).

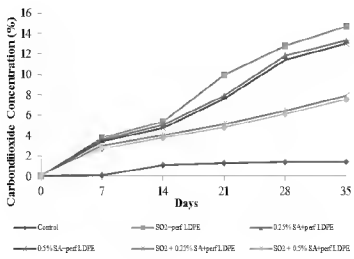
Table 1: Effect of Treatments and MAP on Physical Properties of Litchi Fruits at 2±1°C and 90- 95% RH

Physical Parameters	Storage/Packaging Conditions	Days Post-Harvest					
		0	7	14	21	28	35
PLW(%)	Control	0.00	0.76^{a}	1.37^{a}	1.57^{a}	1.83^{a}	2.00^{a}
	SO_2+perf LDPE	0.00	0.14^{b}	0.29^{b}	0.55^{b}	0.87^{b}	1.10^{b}
	0.25% SA+ perf LDPE	0.00	0.14^{b}	0.26^{b}	0.50^{b}	0.86^{b}	1.02^{c}
	0.5% SA+ perf LDPE	0.00	0.13^{b}	0.25^{b}	0.49^{b}	0.83^{b}	1.01^{c}
	SO_2 + 0.25% SA+ perf LDPE	0.00	0.12^{b}	0.24^{b}	0.45^{b}	0.71^{c}	0.89^{d}
	SO_2 + 0.5% SA+ perf LDPE	0.00	0.12^{b}	0.23^{b}	0.45^{b}	0.64^{c}	0.89^{d}
L*	Control	43.97^{b}	41.49^{b}	37.99^{c}	34.48^{c}	29.27^{c}	23.89^{c}
	SO_2+perf LDPE	70.48^{a}	67.36^{a}	58.27^{a}	52.53^{a}	47.56^{a}	45.91^{a}
	0.25% SA+ perf LDPE	44.36^{b}	41.93^{b}	40.89^{b}	36.46^{b}	30.3^{b}	24.53^{b}
	0.5% SA+ perf LDPE	44.39^{b}	42.75^{b}	41.08^{b}	37.29^{b}	31.46^{b}	25.97^{b}
	SO_2 + 0.25% SA+perf LDPE	70.29^{a}	66.45^{a}	58.31^{a}	52.7^{a}	48.54^{a}	45.97^{a}
	SO_2 + 0.5% SA+perf LDPE	70.41^{a}	66.83^{a}	58.42^{a}	52.77^{a}	48.88^{a}	46.2^{a}
a*	Control	28.26^{a}	25.26^{a}	22.41^{a}	19.51^{a}	15.08^{c}	12.63^{b}
	SO_2+perf LDPE	1.72^{b}	8.02^{b}	12.89^{b}	19.81^{a}	22.77^{b}	26.31^{a}
	0.25% SA+perf LDPE	28.86^{a}	25.93^{a}	23.69^{a}	20.67^{a}	16.88^{c}	13.2^{b}
	0.5% SA+perf LDPE	28.97^{a}	26.39^{a}	24.05^{a}	21.23^{a}	17.19^{c}	13.41^{b}
	SO_2 + 0.25% SA+perf LDPE	1.70^{b}	8.04^{b}	13.63^{b}	20.45^{a}	25.76^{a}	26.73^{a}
	SO_2 + 0.5% SA+perf LDPE	1.73^{b}	8.09^{b}	14.1^{b}	21.38^{a}	26.04^{a}	27.00^{a}
b*	Control	13.27^{a}	11.21^{b}	10.5^{b}	9.83^{b}	9.05^{b}	7.98^{b}
	SO_2+perf LDPE	25.36^{b}	21.01^{a}	17.98^{a}	17.03^{a}	15.52^{a}	14^{a}
	0.25% SA+perf LDPE	13.47^{a}	11.5^{b}	10.54^{b}	10.01^{b}	9.21^{b}	8.11^{b}
	0.5% SA+perf LDPE	13.58^{a}	11.81^{b}	10.98^{b}	10.39^{b}	9.67^{b}	8.53^{b}
	SO_2 + 0.25% SA+perf LDPE	25.57^{b}	21.29^{a}	18.02^{a}	17.14^{a}	16.22^{a}	14.73^{a}
	SO_2 + 0.5% SA+perf LDPE	25.57^{b}	21.84^{a}	18.36^{a}	17.46^{a}	16.73^{a}	15.09^{a}

For each measurement, corresponding mean values followed by different notation implies they are significantly different from each other at 5% level of significance



(a)



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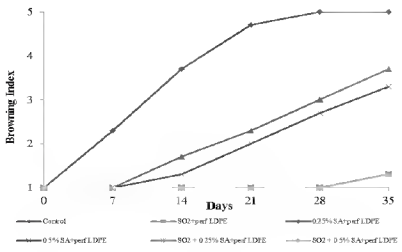

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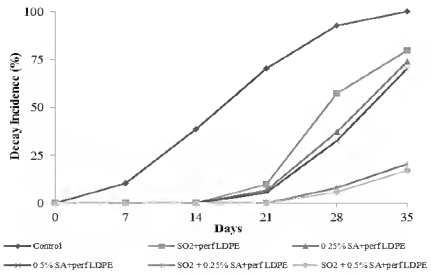

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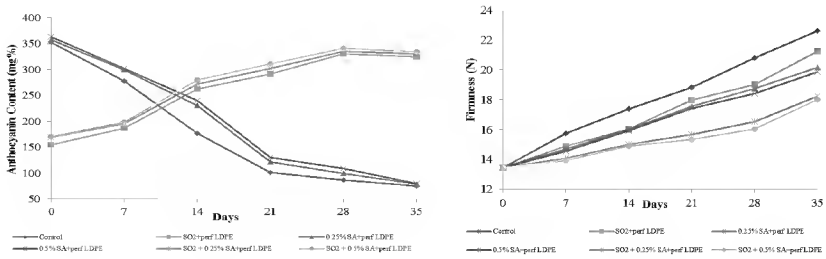

(e) (f)

Figure 1: Variation in Oxygen Concentration (a), Carbon-Dioxide Concentration (b), Pericarp Browning Index (c), Decay Incidence (d), Anthocyanin Content (e) and Firmness (f) of Treated and Ma Packed and Control Litchi Fruits at 2±1°C and 90-95% RH

Firmness

Litchis were very firm initially and resisted 13.46 N force of compression irrespective of the treatments. A gradual increase in firmness was observed in all fruits during storage, the extent of increase depended upon the nature of treatment (Figure 1(f)). A significantly ($p \leq 0.05$) high firmness was observed in SO_2+perforated LDPE treated fruits compared to SA+ LDPE treated fruits and combined SO_2 and SA+ perforated LDPE treated fruits. Fruits treated with treatment SO_2+0.25% SA+ perforated LDPE and SO_2+0.5% SA+ perforated LDPE retained firmness close to that of fresh fruits than fruits treated with acid alone. The increase in firmness may be attributed to desiccation from the fruit, resulting in fruit drying and hardening of pericarp. Fruits in MAP maintained firmness close to that of fresh sample probably because of reduction in dehydration of the pericarp. Increase in firmness was highest in case of control fruits. The results are in corroboration with the finding of Sivakumar & Korsten, 2010 and Mangaraj et al. 2011, who also observed an increase in firmness of litchi during storage.

Effect on Total Soluble Solids, Titratable Acidity and Ascorbic Acid

There was reduction in the TSS, TA and ascorbic acid levels of the fruits from all treatments (Table 2). In the study conducted, highest TSS was retained in fruits treated with SO_2+0.5% SA+ perforated LDPE, followed by SO_2+0.25% SA+ perforated LDPE. The least TSS was observed in control fruits. The fruits treated with 0.25 and 0.5% SA+ perforated LDPE retained moderate levels of TSS (15.23 and 15.37, respectively) comparative to SO_2 fumigated fruits having TSS around 13.97 Brix on 35th day of storage. This suggests that there is a reserve consumption due to the metabolic activity of the fruits (Silva et al. 2010).

A declining trend was observed in titratable acidity for control fruits and fruits treated with SO_2, 0.25 and 0.5% SA+ perforated LDPE alone, whereas a slight increase in TA was observed in fruits treated with SO_2+0.25% SA+ perforated LDPE and SO_2+0.5% SA+ perforated LDPE till 21 days of storage and then decreased gradually during the storage period (Table 2). The increase in TA is the result of direct penetration of SO_2 through skin into aril (Tongdee, 1993), and this effect is enhanced by dipping the fruits in the acid. It can be attributed to the leaching of acid from the pericarp to the aril and subsequent absorption by the aril as suphur fumigation increases the permeability of the plasma membrane and allows the impregnation of acid (Holcroft and Mitcham, 1996). The results of the study are in agreement with the findings of Sivakumar and Korsten (2010), who also observed an increase in titratable acidity of fruits treated with 1-methylcyclopropene and stored under controlled atmosphere conditions.

Treating fruits with salicylic acid significantly maintained the ascorbic acid content, in the fruit pulp over the control fruits and fruits treated with SO_2. The fruits given combined treatment of SO_2+0.5% SA+ perforated LDPE recorded highest ascorbic acid. No significant difference was found in the ascorbic acid contents of SO_2+0.25% SA+ perforated LDPE and SO_2+0.5% SA+ perforated LDPE (Table 2). The fruits treated with SA treatment retained high mean values of TSS, ascorbic acid and TA. This can be due to the fact that it has the ability to delay the ripening process (Leslie and Romani, 1988). The reduction in TSS and ascorbic acid indicates that these may be used as respiratory substrates and as carbon skeletons in the synthesis of new compounds (Reuck et al. 2011). A delay in the process of senescence was also reported in pear treated with salicylic acid (Hassan et al. 2007). Similar results were quoted by Kumar et al. 2013, indicating a decrease in TSS, TA and ascorbic acid of the litchi fruits tested with different antioxidants and salicylic acid.

Table 2: Effect of Treatments and MAP on Biochemical Properties of Litchi Fruits at 2±1°C and90- 95% RH

Biochemical Parameters	Storage/Packaging Conditions	Days Post-Harvest					
		0	7	14	21	28	35
TSS(°B)	Control	19.73^{a}	17.27^{a}	15.13^{b}	13.8^{c}	11.77^{c}	10.7^{c}
	SO_2+perf LDPE	19.7^{a}	17.9^{a}	17.02^{ab}	16.37^{b}	15.12^{b}	13.97^{b}
	0.25% SA+perf LDPE	19.7^{a}	18.1^{a}	17.47^{ab}	16.9^{b}	16.07^{b}	15.23^{b}
	0.5% SA+perf LDPE	19.7^{a}	18.23^{a}	17.73^{ab}	17^{b}	16.27^{b}	15.37^{b}
	SO_2+ 0.25% SA+perf LDPE	19.7^{a}	18.9^{a}	18.2^{a}	17.9^{a}	17.7^{a}	17.4^{a}
	SO_2+ 0.5% SA+perf LDPE	19.7^{a}	18.93^{a}	18.33^{a}	18.1^{a}	17.77^{a}	17.53^{a}
Titratable Acidity	Control	0.38^{a}	0.32^{a}	0.29^{b}	0.24^{c}	0.18^{c}	0.14^{c}
(TA) (%malic acid)	SO_2+perf LDPE	0.38^{a}	0.378^{a}	0.345^{ab}	0.317^{bc}	0.291^{b}	0.269^{b}
	0.25% SA+perf LDPE	0.38^{a}	0.382^{a}	0.376^{a}	0.37^{ab}	0.362^{ab}	0.35^{ab}
	0.5% SA+perf LDPE	0.38^{a}	0.384^{a}	0.378^{a}	0.376^{ab}	0.367^{ab}	0.358^{ab}
	SO_2+ 0.25% SA+perf LDPE	0.38^{a}	0.388^{a}	0.392^{a}	0.403^{ab}	0.4^{a}	0.393^{a}
	SO_2+ 0.5% SA+perf LDPE	0.38^{a}	0.39^{a}	0.398^{a}	0.409^{a}	0.404^{a}	0.395^{a}
Ascorbic Acid mg/100ml juice	Control	39.38^{a}	34.22^{b}	30.42^{b}	23.05^{b}	19.74^{b}	17.03^{b}
	SO_2+perf LDPE	39.37^{a}	35.03^{a}	32.47^{a}	29.34^{a}	26.79^{a}	22.9^{a}
	0.25% SA+perf LDPE	39.38^{a}	35.14^{a}	32.89^{a}	29.93^{a}	26.98^{a}	23^{a}
	0.5% SA+perf LDPE	39.37^{a}	35.3^{a}	33.51^{a}	30.16^{a}	27.03^{a}	23.16^{a}
	SO_2+ 0.25% SA+perf LDPE	39.37^{a}	36.01^{a}	33.66^{a}	30.94^{a}	27.46^{a}	24.26^{a}
	SO_2+ 0.5% SA+perf LDPE	39.37^{a}	36.55^{a}	33.83^{a}	31.31^{a}	27.86^{a}	24.74^{a}
Overall Acceptability	Control	9^{a}	7.5^{c}	6.7^{d}	5.3^{c}	3.8^{c}	2.8^{d}
	SO_2+perf LDPE	8.6^{b}	7.9^{bc}	7.4^{c}	6.9^{b}	5.6^{b}	4.4^{c}
	0.25% SA+perf LDPE	9^{a}	7.9^{bc}	7.6^{bc}	6.9^{b}	5.8^{b}	5^{bc}
	0.5% SA+perf LDPE	9^{a}	8^{b}	7.6^{bc}	6.9^{b}	6^{b}	5.1^{b}
	SO_2+ 0.25% SA+perf LDPE	8.8^{a}	8.5^{a}	8.1^{ab}	7.4^{a}	6.8^{a}	6.1^{a}
	SO_2+ 0.5% SA+perf LDPE	8.8^{a}	8.6^{a}	8.2^{a}	7.6^{a}	6.9^{a}	6.3^{a}

For each measurement, corresponding mean values followed by different notation implies they are significantly different from each other at 5% level of significance.

Overall Acceptability

The analysis of the data showed that storage period and treatments had a significant effect on overall acceptability of the litchi fruits. Maximum mean score of the panellists was recorded for SO_2+0.5% SA+ perforated LDPE (6.3), followed by SO_2+0.25% SA+ perforated LDPE (6.1) while minimum mean score was recorded in control fruits (2.8) on 35th day of storage. The fruits given treatment SO_2+0.5% SA+ perforated LDPE showed highest acceptability among all treatments in terms of retention of red colour, fruit firmness and controlling the decay during storage period (Table 2). The fruits were little acidic in taste. The treatment was able to maintain the overall acceptability upto 21 days, after which the taste and flavour of the fruits altered. The control samples rated poor in terms of overall acceptability because of

development of off flavours, firmness, browning, poor taste and panellist evaluation indicated lower scores for the overall acceptability. The fruits given treatment 0.25% SA+ perforated LDPE and 0.5% SA+ perforated LDPE, maintained overall acceptability till 14 days of storage with good flavour and taste while SO2+ perforated LDPE fruits rated fair in terms of colour retention, fruit firmness and control of decay but they were little acidic in taste and flavour compared to 0.25% SA+ perforated LDPE and 0.5% SA+ perforated LDPE treated fruits.

CONCLUSIONS

The study indicated that the litchi fruit cv. 'Calcutta' treated with 0.6g/kg SO_2 for 20 minutes followed by dip treatment with 0.5%SA for 2 min, air dried and packed in transparent perforated low density polyethylene (100 gauge) packages, maintained the overall quality by controlling pericarp browning, decay and maintaining overall acceptability, thus, extending the shelf life up to 21 days at 2±1°C and 90-95% RH. Salicylic acid extended the quality of litchi but still pilot scale testing/experimentation is required to validate this treatment for browning and decay control and for improving the colour and quality of litchi fruit.

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